Prediction of habitual physical activity level and weight status from fundamental movement skill level

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Prediction of habitual physical activity level and weight status from Fundamental Movement Skill level.

Abstract

Fundamental Movement Skills (FMS) have been assessed in children in order to investigate the issues of the low proportion of children who meet physical activity (PA) guidelines and rising levels of obesity. The aim of this research was to identify whether previous or current FMS level is a better predictor of PA levels and weight status in children. In January 2012 (year one), 281 children were recruited from one primary school in the West Midlands, UK. Children performed eight FMS three times which were videoed and assessed using a subjective checklist. Sprint speed and jump height were measured objectively. Height and mass were measured to calculate BMI to determine weight status. Skinfold calliper readings were used to calculate body fat percentage. One year later in January 2013, all these tests were repeated on the same children, with the additional collection of PA data via the use of pedometers. Following multiple linear regression it was identified that prior mastery in FMS was a better predictor of current PA, whereas current FMS was a better predictor of current weight status. Overall, FMS mastery is needed in childhood to be able to participate in PA and maintain a healthy weight status.

Key Words: Fundamental Movement Skill, Children, Physical Activity, Skill Mastery, Obesity.

Introduction

Higher levels of physical Activity (PA) are related to multiple positive health outcomes in children and adults (Erkisen, Curtis, Gronbaek, Helge and Trolsturp, 2013). PA levels have been tracked from childhood to adolescence (Kelder, Perry, Klepp and Lytle*,* 1994) and from adolescence into adulthood (Kjonniksen, Torsheim and Wold, 2008). In addition, other cardiovascular disease risk factors such as hypertension and high cholesterol also track from childhood into adulthood and are linked to low PA (Wilkinson, Diamond and Miller, 2011). Therefore, it is important to target children as a preventive measure for later life disease related to physical inactivity and obesity.

In order to address the low proportion of children meeting the PA guidelines and increasing obesity, the assessment and development of Fundamental Movement Skills (FMS) in childhood have been examined (Okely and Booth 2004; Mckenzie et al., 2002). FMS form the prerequisites for sport-specific and PA skills (Stodden et al., 2008). Understanding this relationship is therefore important for intervention planning. A review by Lubans, Morgan, Cliff, Barnett and Okley, (2010) highlighted five studies that elucidated that an increased weight status has negative effects on FMS mastery. In all of these studies BMI was used to determine weight status. BMI has been documented to hold limitations, particularly in children (Jackson et al., 2002). However, using alternative methods, such as measuring body composition (fat mass), avoids the limitations of assessing BMI in paediatric populations and is arguably a more important measure in children (Doak et al., 2013).

There are few longitudinal studies that have looked at assessing the relationship between childhood FMS and future PA level (Barnett, Van Beurden, Morgan, Brooks and Beard, 2008). Barnett et al, (2008) and Okely et al (2001) both reported that very small variations in adolescent PA could be predicted from childhood FMS competency. In contrast, Mckenzie et al., (2002) did not identify a relationship between childhood FMS and future PA levels. None of these three studies reassessed FMS competency when they measured the future PA levels. It is therefore not known whether children need to gain FMS mastery in order to participate and maintain participation in PA, or whether an increase in PA participation will develop and increase mastery of FMS (Graff et al., 2004 and Hume et al., 2008). Such information is needed to inform physical education practice and health policy in the UK. The objective of this study will be to predict the variation of PA (average daily steps) and weight status (body fat % and BMI) at time point two from the FMS measures at time point one and two. The aim of this study was to identify whether FMS measured one year previous or FMS measured at the same time point is a better predictor of PA levels and weight status in children. This study is novel as it will assess FMS at two time points and identify which time point can best predict variation in PA which other studies have failed to do (Graf et al., 2004; Barnett et al., 2008 and Okley et al., 2001). Based on Stodden et al's (2008) theoretical model it would be hypothesised that current FMS will be a better predictor of PA, as the model suggests that PA is a direct consequence of motor competence (FMS level).

Method

Sample

Following Institutional ethical consent the present study began in January 2012 (year one). A sample of 292 children were recruited from one primary school in the West Midlands, England. Informed consent from parents/guardians was gained from 281 children (129 boys, 152 girls) who then participated in the study. Year groups two-six (age 6-11 years) were assessed with an overall mean (±SD) age of 8.9 years (± 1.4 years). From the sample, 84% of the children were White British, 15% were Asian and1% was Afro-Carrabin, and this is a representative sample of the ethnic diversity for the West Midlands (Coventry City Council, 2013). The local council's lead advisory teacher for Physical Education assisted in the selection of the chosen school. This was to ensure that the school was broadly representative (was within the 50-59% bracket of electoral wards for deprivation and socio-economic status within the city and nationally (Coventry City Council, Key Statistics, 2012)) of primary schools within the city. The school was also within the mid-range of electoral wards for deprivation and socio economic status for the city in question. Between the years of testing children had their scheduled Physical Education lessons but had not received any additional PA programs during or between testing periods.

The data collection was repeated one year later in 2013 (year two). There was a 90% follow up rate of 252 (116 boys and 136 girls) children (90% follow up rate), with a mean age of 9.8 years (± 1.4 years).

Anthropometric Measurement

Table 1 displays the proportion of normal and overweight/obese children in year one (2012) and year two (2013) determined by BMI and Body fat percentage.

BMI

Height (cm) and mass (kg) were recorded to the nearest cm and 0.1kg respectively using a stadiometer (SECA Instruments, Ltd, Germany) and electronic weighing scales (SECA, Instruments, Ltd, Germany), respectively. BMI was calculated as Kg/m^2, the 1990 reference curves controlling for age and sex were used to identify overweight and obese children (Cole, Freeman and Preece, 1990). Children were classed as overweight if they were in the 85^{th} centile and obese if in the 95^{th} centile (Cole, Freeman and Preece, 1990).

Body fat percentage (BF%)

BF% was calculated using skinfold assessment from two sites; tricep and medial calf. Two measures from these two sites were taken following guidelines from Thompson et al., (2009) and according to the International Society for the Advancement of Kinanthropometry (ISAK) criteria. The Slaughter et al. (1988) skin fold equation (Body Fat % = (0.735*(Tricep+Medial Calf))+1) was used to calculate each participant's body fat percentage. The same trained researcher took the skin fold measurements each year to maintain consistency and the technical error of measurement at the tricep and medial calf was 4.57% and 4.12% respectively, showing appropriate intratester reliability. Body fat reference curves controlling for age and sex were used to identify overweight and obese children (McCarthy, Cole, Fry, Jebb and Prentice, 2006). Children who fell in to the 85^{th} centile were classed as overweight and children who fell in to the 95^{th} centile were obese (McCarthy et al., 2006).

Fundamental Movement Skill assessment

Subjective Measurement

FMS was assessed using the Process Orient Checklist (POC) taken from the New South Wales 'Move it Groove it; Physical activity in primary schools: Summary Report' (2003). The checklist was comprised of eight individual FMS (Sprint Run, Side Gallop, Hop, Kick, Catch, Overarm Throw, Vertical Jump and Static Balance) and each skill was broken down into five or six components. (e.g. sprint run is broken down into six components; 1: Land on ball of foot, 2: Non-support foot bent at least 90^{o} in recovery, 3: High knee lift, thigh parallel to ground, 4: Head and trunk stable eyes forwards, 5: Elbows bent at 90^{o}, 6: Arms drive forward and back, opposite legs).

Each skill was demonstrated to the children once by a researcher, with no coaching points between attempts, in accordance with 'Move it Groove it' (NSW, 2003) guidelines. Each child performed each skill three times with no feedback. Trained researchers (according to the guidelines (NSW, 2003)) assisted in the recording of the FMS. The eight FMS were split into locomotor (sprint, hop and gallop) were recorded on the sagittal plane and static (balance, jump, catch, kick and throw) skills on the coronal plane (Knudson and Morrison 2002). The performance of each FMS was video recorded at 50 frames per second (Sony video camera, Sony, UK) and subsequently analysed using Quintic biomechanics analysis software (Quintic Consultancy Ltd, UK). The POC was used to determine the mastery level of the skill. Due to the eight FMS consisting of five or six components a percentage was calculated to make the score for the individual scores to be comparable. For example, for the sprint run if three out of six components were present when the skill was performed they would be given 50% mastery of that skill. After all three attempts, each skill was analysed and an average percentage of mastery was calculated and used in the analysis. Prior to analysis inter rater reliability was conducted in year one and year two producing a score of 90.3% and intra rater reliability was 97.6% demonstrating good reliability (Jones, Okely, Caputi and Cliff, 2010).

Objective measurement

A 10 meter sprint run was timed using smart speed gates (Fusion Sport, Australia). Two laser gates were set up 10 meters apart with the participant having a flying start to ensure that sprint speed was measured independently of the acceleration phase. Vertical jump height was measured using a myo test (Myo test TECH, France). The height and mass of each participant was entered into the myo test. The device was attached to a belt on the waist of the participant. When the belt beeped three consecutive jumps were performed. The myo test produced the best jump height for the participant which was recorded and used for analysis.

Physical Activity (PA)

Physical activity was assessed using a sealed, piezo-electric pedometer (New Lifestyles, NL2000, Montana, USA) worn over four days (two weekdays and two weekend days (Riddoch et al., 2004)). Four days of monitoring is a sufficient length of time to determine habitual physical activity levels in children (Trost, Pate, Freedson, Sallis and Taylor, 2000). Children were given a pedometer on a

Wednesday with an explanation and demonstration of how to use it and when to record their steps. They were given a sheet with a table on to record the steps, which included written instructions for parents/guardians to help. The pedometers were given out a day early to allow the children to practise using it before the data collection commenced. From these recordings average daily step, average weekend step and average weekday step counts were calculated for the analysis (Table 2.)

Statistical Analysis

Regression relationships were analysed between all 20 variables and age. For the 15 out of 20 variables that were significantly related to age, unstandardized age residuals were calculated to remove age as a confounding factor (James et al., 2005). Once this was completed the Q-Q plot and the kurtosis and skewness values for each variable were assessed with normal distribution being indicated as between <1 and >-1 (Kline, 2005). The two variables that were not normally distributed (kick year 1 and speed year 1) were initially arcsine transformed: $y_1 = 2\times\arcsin(\sqrt{y})$ (Black, 1999). Arcsine transformation caused kick 1, but not speed year 1, to become normally distributed. Square root transformation still caused the values for speed 1 to be non-normal, but closer to the desirable kurtosis and skewness values (0.882 and 1.493, respectively). A further consideration of the Q-Q plot identified that speed 1 showed two values that were large outliers. These two participants were removed from the data set. Once these were removed values for kurtosis and skewness became normal. Discriminant function analysis was carried out on the complete data set to identify whether boys and girls were significantly different groups and should therefore be analysed separately. For boys and girls the Wilks

Lambda value (0.514, p=<0.001) was significant indicating that boys and girls were significantly different and should be analysed separately. Multiple linear regression analysis, with use of the enter method, was used to assess the multicollinearity of the variables in the data set. Values were checked for their VIF (variable inflation factor) value. All variables had a VIF <2 which identified that a stepwise multiple linear regression analysis would be an appropriate method to analyse the data sets. The statistical package for social sciences (SPSS inc, Version 20) was used for all analysis and statistical significance was set at P = .05 a priori.

Results

Table 1 displays that over the year that the children have been tested the number of children of a normal weight has decreased and the number of overweight/obese has increased, however, this change is not significant (P=>.05).

table 1 near here

Table 2 displays that boys are significantly more active than girls (p=<0.05) and that both boys and girls are both more active on weekdays compared to weekend days, however this is only significant for boys (p=<0.05).

table 2 near here

Multiple linear regression with a stepwise method was used to produce models to predict variation in the dependent variable (Table 3). In each case the FMS variable that predicted the highest amount of variation was retained in the model. Overall for both boys and girls, current FMS was a better predictor of current weight status (BMI and BF%). However, for both boys and girls previous FMS mastery levels were better predictors of future PA levels.

As mentioned in the statistical section in the methods boys and girls were identified as being significantly different groups when measuring FMS. Below are the results for Boys and Girls when controlled for age.

Boys (age independent data)

Differences, between individuals, in jump height in year two predicted more of the variation in BMI in year two than in year one (6.3% compared with 3.1%). Variation in jump height in year two predicted more of the inter-individual differences in BF% in year two than in year one (13.8 compared with 12.6%). Differences between individuals, in the catch in year one predicted more of the variation in average daily steps in year two, whereas variation from any FMS in year two did not predict any differences in average daily steps. Variation in the catch and sprint speed in year one predicted more of the inter-individual differences in average weekday steps in year two compared to the FMS in year two (17.6% compared to 5.9%). Differences between individuals in FMS in year one or in year two failed to predict variation in average weekend steps in year two.

Girls (age independent data)

Differences between individuals, in jump height in year two predicted more of the variation in BMI in year two than in year one (12% and 5.3% respectively). Variation in jump height in year two predicted more of inter-individual differences in BF% in year 2 than in year one (15% and 12.9% respectively). Differences between individuals, in the hop in year one predicted more of the variation in average daily steps in year two (24.1% compared to 10.8% respectively). Variation in the hop in year one predicted more of the inter-individual differences in average weekday steps in year two (21.8% compared to 10.9% respectively). Differences between individuals in jump height in year one predicted more of the variation in average weekend steps in year two (13.5% compared to 6.2% respectively).

Table 3 near here

Discussion

The purpose of this study was to identify whether previous or current FMS level best predicted future PA levels and weight status. The results highlight that previous FMS levels are the better predictor of future PA levels, whereas current FMS levels are better predictors of current weight status when determined using BMI and BF%.

For BMI, figures have virtually stayed the same, with approximately 70% of children being classed as normal weight and 30% of children as overweight or obese. This is representative of children in England according to The Health and Social Care Information Centre, Lifestyles Statistics (2013) reports that 29.5% of children are overweight or obese.

In the present study, although individual differences in current FMS does predict variation in current PA levels, FMS one year earlier predicted a larger percentage of the variation in PA levels in year two. This suggests that mastery in FMS is needed for an increased level of PA participation, rather than increased time spent in PA to increase FMS mastery. Previous research has failed to determine this due to only assessing baseline measurements or not testing FMS when assessing PA in follow up studies (Barnett et al., 2008 and Mckenzie et al., 2002). The results from the current study align with Stodden et al.'s, (2008) theoretical model. Stodden et al.'s (2008) model indicates that FMS needs to be learnt and practised to influence an uptake and maintenance of PA, in agreement with the principle that FMS should theoretically be a better predictor of future PA levels. This model also supports our findings that current FMS will predict current weight status.

The highest predictor of variation in PA was in girls, whereby individual differences in the hop performance in year one predicted 24.1% of the variation in the average daily steps in year two. Hop is a locomotor skill and Vandaele, Cools, de Decker, and de Martelae (2011) highlighted that children have a lower mastery level of locomotor skills when compared to other FMS. Locomotor skills are harder to master because they involve moving the whole body mass from one point to another whilst simultaneously coordinating all parts and sides of the body to produce the movement (Westerndorp, Houwen, Hartman and Visscher, 2011). The hop is one of the harder FMS to master, due to the shift of body mass on to one leg. This not only doubles the weight on that one leg, but decreases the base of support, therefore making it harder for the centre of gravity to stay within the latter and for the child to remain on balance (Burkett, 2010). The difficulty is further exacerbated by the increased motor control and coordinative factors required to swing the resting leg and arms to aid the movement of the hop. By developing the skills to be able to master the hop, it is more likely that individuals will have mastery of the other FMS and therefore engage in more PA. This is however speculative as to why hop performance one year prior to PA assessment contributes to the prediction of 24.1% of the variation of PA in girls.

In boys, individual differences in FMS in year one predicted 17.6% of the variation in average weekday steps one year later, with catch and sprint speed contributing to the model. Both Okely and Booth (2004) and Vandaele et al., (2011) have shown that boys have a higher mastery of object control skills compared to girls. Boys are more likely to engage in ball games, organised games and utilise space around them (Blatchford et al., 2003; Okely et al., 2001). Therefore, for boys to partake and maintain participation in these organised activities mastery of object control skills, such as the catch, is essential. In both boys and girls, the prediction of variation in average weekday steps, by variation in FMS, is higher than prediction of average weekend steps. The current study has indicated that children are more physically active in the week compared to weekends and that boys are more physically active than girls, which is consistent with previous research (Rowlands, Pilgrim, and Eston, 2008). Rowland et al. (2008) analysed physical activity patterns in British primary school children and identified that a decrease in PA at the weekend was due to a drop in light intensity exercise lasting more than five minutes and a drop in frequency of high intensity PA bouts. Westerterp and Plasqui (2004) highlighted that it is these low and high intensity activities, rather than moderate PA, are the main contributors to a child’s PA status. Mota, Santos, Guerra, Ribeiro and Duarte, (2003) assessed PA levels in children but took into consideration PA in school and PA after school/evenings. In their study, girls’ PA was predominantly made up of PA from the school day, whereas PA for boys was mainly executed after school. This suggests that boys are more likely to participate in school sports clubs compared to girls.

When the initial regression analysis was conducted on all 20 variables, 15 were significantly influenced by age. For these 15 independent variables, age could be masking the true variation of the dependent variables. Therefore, age residuals were analysed for these 15 variables to ensure that all analyses undertaken in this study considered the effects of FMS independently of the effects of age. Barnett et al., (2008) reported that object control skills can predict 12.7% of variation in moderate to vigorous PA (MVPA) in adolescents. It was identified that 'grade' significantly affected the variables measured. When using school grade, there could be up to 12 months between children from the same 'grade' and therefore this could have been masking the true effect of the object control skills on MVPA. However, like the current study if the effect of age was controlled for and a higher prediction of PA may have been reported. This is important because recent research has identified relative age effects in the performance of some tests of physical performance, including vertical jump, in a non-sport specific population of British children (Sandercock et al., 2013). Future research examining whether there is a relative age effect in performance of FMS may be of particular interest to teachers and coaches.

In addition Barnett et al., (2008) reported overall gender differences in FMS but didn't analyse them separately when conducting the regression analyses. In the current study, discriminative function analysis identified males and females as being significantly different groups and once analysed separately larger variations were explained for each gender group. For example, FMS in year 1 predicted 7.2% of variation in average daily steps when boys and girls data was combined. When analysed separately 24.1% and 17.6% of variation in average daily steps was predicted in girls and boys, respectively. Therefore, prior studies that have analysed the data combining both genders may not be reporting the true effects of variation in FMS (Barnett et al., 2008).

Children in the current study were at a pre-pubertal stage of maturation and theoretically should be biologically the same (Malina et al., 2004; Thomas and French 1985). The current study identified that boys were significantly better at the kick and catch, whereas girls were better at balancing, this is consistent with previous research (Bryant et al., 2013; Okely and Booth, 2004; Vandaele et al., 2011). Children are socialised in to specific types of PA based upon their gender (Blakemore and Renee, 2005) suggesting why some skills are more important for predicting variation in PA depending on gender. It is however important to stress that equal opportunities need to be provided for both genders so that all FMS can be learned, practised and developed.

The present study holds limitations; the first being the use of pedometers in children. Adherence to strict wear time criteria can be more problematic in children compared to adults and pedometry is not able to distinguish the intensity and type of PA. To overcome this issue, children were given diaries to record with parents when they did not wear the pedometer and any children who had values <1000 steps or >40,000 steps per day were excluded from the analysis (Rowe, Mahar, Raedeke, and Lore, 2004). Identifying the intensity and type of the activities completed would be beneficial. However, for the present study the measurement of habitual PA was the objective of which Riddoch et al., (2004) identified pedometery to be a valid tool to obtain this objective. An additional limitation of the study is the method used to predict BF%. The sample of children would have been a mixture of pre pubertal and pubertal. Thus, perhaps an age and sex specific equation would be more appropriate for future work (Rodriguez et al., 2005) compared to Slaughter et al's (1988) equation which does not take these individual characteristics. However, the method used in the current study has been validated in the literature (Parker, Reilly, Slater, Wells and Pitsiladis, 2003). Furthermore, this method was the most appropriate due to it only needing two skinfolds taken that were non-invasive and time efficient with the large sample size.

The limitations of the use of BMI in paediatric populations has been identified. However, it was included in the present study for comparative purposes with other studies. In addition, BMI is the recommended method to classify weight status by the International Obesity Task Force (IOTF) and in the UK it is the way in which policy and government assess weight status in children.

The current study has identified previous FMS are better predictors of current PA levels. Therefore, FMS needs to be learned and practiced for future success in participation and maintenance of PA. The results from this study suggest that FMS should be tested in primary schools so weaknesses can be identified in children so they can be improved via intervention. Bryant et al., (2013) highlighted that children aged 8-10 years old have a decrease in mastery level in specific skills; therefore this would be a good target age for intervention. These results should be used to influence physical education and health policy in the UK to help decrease obesity levels by increasing PA levels. Not only would a sustained level of PA benefit obesity but would also have other health benefits such as health related fitness and mental wellbeing of the child.

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Table 1. Mean (±SD) BMI and BF values, and percentage of normal and overweight/obese children, in year 1 (2012) and year 2 (2013) determined by 85th and 95th centiles according to Cole et al., (2000) for BMI and McCarthy et al., (2006).

BMI	**Normal weight (%)**	**Overweight/obese (%)**	**Mean (±SD)**
Year 1	70	30	17.5 (2.9)
Year 2	69	31	17.7 (3.4)
BF%			
Year 1	78	22	14.6 (2.9)
Year 2	60	40	21.9 (8.5)

Table 2. Mean (±SD) step counts for daily, weekend and weekday habitual PA.

Gender	Daily Steps (±SD)	Weekend steps (±SD)	Weekday steps (±SD)
Combined	8820 (3724)	8005 (4316)	9603(4053)
Boys	9712 (3816)	8819 (4427)	10514 (4236)
Girls	8064 (3488)	7314 (4116)	8830 (3741)

Table 3.a. Multiple linear regression models that significantly predicted variation in the dependent variable via the use of age residuals of functional movement skills in boys..

D Variable	β slope	P value	% of Variation	Skills 1	β slope	P value	% of Variation	Skills 2
BMI 1	-	-	-	-	-1.694	0.037	3.1	Jump ht 2
BMI 2	-	-	-	-	-2.581	0.005	6.3	Jump ht 2
BF % 1	-	-	-	-	-2.375	0.01	5.3	Jump ht 2
					-1.559	0.005	8.0	Balance 2
					1.619	0.001	12.6	Jump 2
BF % 2	-8.155	0.048	3.8	Catch 1	-10.967	0.000	13.8	Jump ht 2
Av Daily Steps	3623	0.029	6.7	Catch 1	-	-	-	-
Av WE Steps	-	-	-	-	-	-	-	-
Av WD Steps	4307	0.006	11.2	Catch 1	3138	0.019	5.9	Run 2

	9632	0.002	17.6	Speed 1	

Table 3.b. Multiple linear regression models that significantly predicted variation in the dependent variable via the use of age residuals of functional movement skills in girls.

D Variable	β slope	P value	% of Variation	Skills 1	β slope	P value	% of Variation	Skills 2
BMI 1	-	-	-	-	-3.146	0.000	12.0	Jump ht 2
BMI 2	-	-	-	-	-4.117	0.000	15.3	Jump ht 2
BF % 1	-1.403	0.009	6.3	Throw 1	-3.166	0.000	12.9	Jump ht 2
BF % 2	-	-	-	-	-10.702	0.000	15.0	Jump ht 2
Av Daily Steps	3452	0.001	16.3	Jump ht 1	2564	0.002	10.8	Hop 2
	3178	0.000	24.1	Hop 1				
Av WE Steps	4309	0.002	13.5	Jump ht 1	2586	0.014	6.2	Jump ht 2
Av WD Steps	3890	0.001	14.6	Hop 1	2983	0.002	10.9	Hop 2
	3016	0.000	21.8	Jump ht 1				